EVALUATION OF MILITARY COMMUNICATION SYSTEM IN WARFARE

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In this paper, a probabilistic model has been developed which highlights the role of communication system in a warfare. The defensive force is assumed to be divided between fighting units and the jamming units, while the enemy force is comprised of fighting units and the reconnaissance-communication units. The mathematical formulation leads to the evaluation of survival probability of a defence target against an enemy attack. Quantitative results have been discussed as an aid to commander's decision for several specific values of given parameters.

Over the last decade, a number of major efforts have been made to use quantitative analysis to measure the effectiveness of alternative mixes of military forces and weapon systems. Presently, such mixes and increased capabilities of different weapon systems have completely changed the modern warfare.

In any country, there are many strategic installations which become targets for an attacking enemy. In a deterent posture, such as, is the present policy in a democratic country like India, it is required to know the survivability of an installation against the offensive forces using different types of mixes of forces and weapon systems.

In these days of advanced electronic warfare the role of communication system is intuitively obvious. It is an essential factor in the coordination of efforts of the independent men, weapons and base units. It is needless to emphasize that without it a commander cannot command, the intelligence obtained by a reconnaissance is useless, supplies cannot be ordered, damages cannot be correctly assessed and as such the whole system becomes ineffective.

In this paper, we therefore, discuss a general problem of quantitative determination of role of communication in warfare and illustrate an approach by exploring a mathematical model of a battle in which communication is a major system to play a specific role.

NOTATIONS

x = the number of defensive fighting units that can be traded for one jamming unit ($x \leqslant 1$)

M_d = measure of the size of the defenders total force

D_f = the number of defensive fighting units

D_j = the number of defensive jamming units

P_1 = probability of a defensive jamming unit, jamming a message from the enemy reconnaissance communication unit

P_2 = probability that a defensive fighting unit will prevent the enemy from launching its weapon against the target

y = the number of enemy fighting units that can be traded for one reconnaissance-communication unit ($y \leqslant 1$)

M_e = measure of the size of the enemy total force

E_f = the number of enemy fighting units

E_r = the number of enemy reconnaissance-communication units

q_1 = probability that the weapon launched from the enemy unit will destroy the target

q_2 = probability that the enemy reconnaissance-communication unit will receive the correct information regarding the location of the target and will transmit the information to its own base

P_k = probability of killing a target

P_s = probability that the target will survive $=(1-P_k)$

P_r = probability that at least one message will be received from E_r reconnaissance-communicati n units

P_f = probability that at least one of the E_f fighting units will destroy the target

MATHEMATICAL MODEL

The formulation presented here, is of a battle in which a commander of the defensive force is given the task of defending an installation against an enemy attack. His forces are assumed to be divided between D_f fighting units and D_j jamming units, while the enemy forces is comprised of E_j fighting units and E_r reconnaissance-communication units. For a reconnaissance unit to be successful, it should be able to transmit its message without being jammed from any one of the D_j jamming units. Hence, P_r can be expressed as,

$$P_r = 1 - \left\{ 1 - q_2 \, (1-P_1)^{D_j} \right\}^{E_r} \tag{1}$$

which is a measure of the enemy's reconnaissance-communication efficiency.

After obtaining the information regarding the location of the target, the enemy fighting forces are put in action to destroy it. Each of these fighting units E_f must fight D_f defensive units. Therefore, P_f can be written as

$$P_f = 1 - \left\{ 1 - q_1 \, (1 - P_2)^{D_f} \right\}^{E_f} \tag{2}$$

which is a measure of the efficiency of the enemy's fighting units.

We can express the kill probability P_k, that the target will be destroyed, as :

$$P_k = (P_f) \, (P_r) \tag{3}$$

Hence, we can obtain the probability P_s, that the target will survive as

$$P_s = 1 - P_k$$

$$= 1 - \left[1 - \left\{ 1 - q_2'(1 - P_1)^{D_j} \right\}^{E_r} \right] \left[1 - \left\{ 1 - q_1 \, (1 - P_2)^{D_f} \right\}^{E_f} \right] \tag{4}$$

Since, it is assumed that each jamming unit can be traded for x units of D_f units and each reconnaissance unit can be traded for y units of E_f units, then

$$M_d = D_f + x \, D_f, \tag{5}$$

and

$$M_e = E_f + y \, E_r \tag{6}$$

Making use of relations (5) and (6) in (4), we get

$$P_s = 1 - \left[1 - \left\{ 1 - q_1 \, (1 - p_2)^{M_d - x D_j} \right\}^{M_e - y E_r} \right] \times \left[1 - \left\{ 1 - q_2 \, (1 - P_2)^{D_j} \right\}^{E_r} \right] \tag{7}$$

The defensive commander would like to get the optimum value of the survival probability P_s for a given set of parameters.

CASE STUDY

For a given set of values, the mathematical model generates a gain matrix.

Let, $x = y = 1$

and $P_1 = 0{\cdot}2$, $P_2 = 0{\cdot}3$, $q_1 = 0{\cdot}8$, $q_2 = 0{\cdot}7$

$M_d = M_e = {\cdot}5$

Then, by means of relation (7), a 6×6 gain matrix for the values of P_s is generated, with D_j and E_r varying from 0 to 5, and is given in Table 1.

TABLE 1

GAIN MATRIX FOR P_s

Defence chooses D_j	Enemy chooses E_r					
	0	1	2	3	4	5
0	1	0·69	0·68	0·76	0·87	1
1	1	0·68	0·62	0·68	0·82	1
2	1	0·68	0·57	0·61	0·75	1
3	1	0·69	0·55	0·54	0·68	1
4	1	0·72	0·55	0·49	0·59	1
5	1	0·77	0·60	0·48	0·49	1

From Table 1, the commander chooses his strategy to obtain the expected probability of surviva against the different values of the number of enemy reconnaissance units.

Commander Decisions Using Table 2

Let

$$P_1 = 0{\cdot}1 \text{ and } 0{\cdot}3, P_2 = 0{\cdot}2, q_1 = 0{\cdot}4 \text{ and } 0{\cdot}6$$

$$q_2 = 0{\cdot}2, 0{\cdot}4, 0{\cdot}6, 0{\cdot}8 \text{ and } 1{\cdot}0$$

$$M_d = M_e = 5 = D_j$$

TABLE 2

P_s FOR VARIOUS VALUES OF q_2, q_1 AND P_1

q_2	$q_1=0{\cdot}4$		$q_1=0{\cdot}6$	
	$P_1 = 0{\cdot}1$	$P_1 = 0{\cdot}3$	$P_1 = 0{\cdot}1$	$P_1 = 0{\cdot}3$
0·2	0·77	0·92	0·69	0·90
0·4	0·63	0·85	0·51	0·80
0·6	0·55	0·79	0·41	0·73
0·8	0·52	0·74	0·36	0·66
1·0	0·50	0·70	0·34	0·60

From Table 2, it is obvious that : (i) If the defensive jamming units become more effective (i.e., if the value of P_1 increases), there is a considerable increase in the probability of survival of the target. (ii) If the probability of destruction by the enemy weapon increases (say in the case of guided missiles or use of nuclear warhead), then the survival probability decreases as far as defence is concerned. (iii) In every case, if the enemy's reconnaissance-communication system becomes more efficient, the survival probability of the defence target decreases (Ref. Table 2).

Commander Decisions Using Table 3.

Let

$$P_1 = 0{\cdot}01, 0{\cdot}10, 0{\cdot}20, 0{\cdot}50 \text{ and } 0{\cdot}70$$

$$P_2 = 0{\cdot}2, q_1 = q_2 = 0{\cdot}6, y = 0{\cdot}6$$

$$x = 0{\cdot}0, 0{\cdot}2, 0{\cdot}4, 0{\cdot}6, 0.8 \text{ and } 1{\cdot}0$$

TABLE 3

P_s FOR VARIOUS VALUES OF P_1

x	$P_1 = 0{\cdot}01$	$P_1 = 0{\cdot}10$	$P_1 = 0{\cdot}2$	$P_1 = 0{\cdot}5$	$P_1 = 0{\cdot}7$
0	0·65	0·69	0·76	0·97	0·99
0·2	0·58	0·62	0·71	0·96	0·99
0·4	0·49	0·59	0·65	0·95	0·99
0·6	0·39	0·45	0·59	0·94	0·99
0·8	0·28	0·35	0·52	0·93	0·99
1·0	0·17	0·25	0·44	0·92	0·99

From Table 3, it may be observed that : (i) As the number of defensive fighting units, that can be traded for one jamming unit increases, the probability of survival decreases. In other words, commander should choose to have more fighting units rather than having the jamming units (for the chosen value of the parameters). (ii) For each x, the probability of survival increases as the efficiency of jamming units improves. (iii) As far as effectiveness in terms of target survivability is concerned, the optimum value of probability of jamming units is $0{\cdot}7$. Ultimately this may also lead to a balance between cost and efficiency.

CONCLUSION

It must be remembered that the model presented here is of a particular type of battle and thus the results are useful only in so far as some real situations can be realistically related to the model.

Moreover, such types of systematic studies help the commander to choose the specific values of the parameters so as to achieve the desired results. It may also be borne in mind that such types of studies are only a beginning and it is felt that further insight into the problem may lead to more realistic solutions of the battle situation.

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